National Defence / Defense nationale

DEFENCE AND CIVIL INSTITUTE OF ENVIRONMENTAL MEDICINE

Canada

May 1987

DCIEM No. 87-RR-18

A COMPARISON OF RECTAL, AUDITORY CANAL AND ESOPHAGEAL TEMPERATURE SITES DURING REWARMING FROM MILD HYPOTHERMIA

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ABSTRACT

Eight healthy male volunteers (aged 21 to 32 yrs) were cooled in 22°C water on three occasions and immediately rewarmed once each by inhalation of 45°C humidified air by immersion in 40°C water and by spontaneous shivering. Three measures of deep body temperature, rectal, auditory canal, and esophageal were followed during the cooling and the subsequent rewarming. There were no differences in the measured rate of cooling between the three core temperature sites. Rewarming for each temperature site was analyzed by the magnitude of afterdrop by the duration of afterdrop and by the rate of rewarming. Regardless of which rewarming technique was studies, temperatures measured at the esophageal site always showed the least after drop in both magnitude and duration as compared to the rectal and auditory canal sites. While there were no differences in the rewarming rates calculated for each of the three sites during inhalation or spontaneous rewarming, auditory canal and esophaeal sites were observed to have significantly greater rewarming rates than rectal during rapid rewarming in 40°C water. The results show that the esophageal site is the most sensitive to changes in deep body temperature during rewarming and would be the method of choice if it were simpler to measure. However, during rewarming in which there is a slow rate of rewarming as in spontaneous or inhalation rewarming, all three sites appear to be equally as effective in reflecting rewarming rates.

INTRODUCTION

The major goal of rewarming a hypothermic victim is to raise the body temperature to within normal ranges without precipitating any undesirable side effects. The greatest concern during the rewarming is the sensitivity of cold cardiac tissue to ventricular fibrillation (1), cardiac arrest (2), or cardiovascular collapse due to a reduced cardiac output (3). Although the closest approximation of cardiac temperature would be esophageal temperature (4), the majority of all studies evaluating various rewarming techniques have measured only auditory canal or tympanic temperatures along with rectal temperature (5,6,7,8,9,10).

Hayward and Steinman (10) did, however, record esophageal temperature in one of their ten subjects: and Lloyd (11) monitored esophageal temperature in an unspecified number of hypothermic victims. both studies indicated esophageal temperature was much quicker to respond to inhalation rewarming than rectal. Hoskin, Melinyshyn, Romet, and Goode (12) recorded all three temperatures, auditory canal, esophageal and rectal in a study comparing whole body versus trunk-only rewarming in 40°C water and showed both esophageal and auditory canal temperatures rising simultaneously and at quicker rates than rectal. Hayward, Edkerson, and Kemna (13) compared esophageal temperature directly with cardiac temperature during inhalation, immersion in 40°C water abd spontaneous rewarming but only on one subject. He did show however, a direct correlation between the two measurement sites.

There still remains however, a paucity of data relating esophageal temperature, which could be used to approximate cardiac temperature to changes in auditory canal or rectal temperature during cooling and rewarming. The purpose of this study was to increase the available data on comparisons of deep body temperature during cooling and rewarming and to determine whether any differences could affect the interpretation of the efficacy of different rewarming techniques.

METHODS

Eight healthy males (aged 21 to 32) volunteered to participate in a study comparing three different rewarming techniques, rapid external rewarming in 40°C water, inhalation, rewarming, and spontaneously bys hivering (14). The physical characteristics, height, weight, and percent body fat were determined for each subject and are presented in Table 1.

Core Temperature Measurements

Rectal temperature was measured by a thermistor probe (YSI 401) inserted 15 cm beyond the anal sphincter. Esophageal temperature was measured by passing a thermistor (YSI, Type 4004), sealed in the tip of a 1.5 mm diameter flexible polyethylene catheter, into the esophagus via the nose until the tip of the thermistor was 43 cm from the nostril.

This distance has been shown to place the thermistor approximately at the level of the heat (13,15). auditory canal temperature was measured with a thermistor sealed in the tip of a polyethylene catheter identical to the esophageal probe, attached to the tip of cotton swab and carefully inserted into the auditory canal. When the subject experienced some discomfort, the thermistor was withdrawn 1-2 mm and fixed to the pinna of the ear with surgical tape. Cotton wool was then packed over the opening of the auditory canal. Temperatures were recorded every minute during cooling and rewarming using an automated data acquisition system (HP85 computer, 3974A Scanner#Voltmeter).

PROTOCOL

All experiments were carried out in a laboratory controlled at 21°C and 50% humidity. The subjects arrived and changed into swim trunks, fitted with thermistors. They were then allowed to rest for 30 minutes, laying on a cot and covered by a blanket. Recording of the temperatures began during this rest period and continued until the completion of the rewarming phase. Following the rest period, the subjects were immersed in a whole body water calorimeter (16) controlled at 22°C. They were immersed for 60 minutes, or less if either their rectal temperature had fallen 1°C from pre-immersion values or to 35.5 °C. Following cooling, the subjects were removed from the calimeter and moved to the appropriate rewarming site. The time from being removed from the calorimeter to the start of a rewarming technique never exceeded 3 minutes.

Rewarming for each subject was carried out once by each technique, inhalation of humidified 45°C air, immersion in 40°C water or spontaneously through shivering. A more detailed description of the rewarming techniques has been reportedearlier (14).

ANALYSIS

The cooling rates were calculated for each temperature site for the final 30 minutes of immersion, by which time all subjects had started to show a decline in deep body temperature. Three parameters were calculated to describe the rewarming pattern of each temperature site. They were the magnitude of the afterdrop (the decline in temperature once the subject was removed from the cold water), the duration of time for the temperature to reach its minimum temperature and the rewarming rate at each temperature site after reaching its minimum value.

Statistical analyses comparing the core measurement sites for each parameter were carried out by a one-way analysis of variance with differences between means determined by Student,s t-test for independent means.

RESULTS

Table 2 shows a comparison of the cooling rates at the three temperature sites for the three rewarming techniques. There were no significant differences between cooling rates between the three temperature sites prior to any rewarming. Rates calculated from the auditory canal tended to be lower than for the other two sites.

Figure 1 displays the magnitude of the afterdrop for each rewarming technique measured at each temperature site. In all rewarming conditions, the esophageal site showed the smallest afterdrop. The magnitude was significantly less than that observed at the rectum or auditory canal during the spontaneous rewarming. During the inhalation rewarming, the magnitude at both the esohpagus and the auditory canal were significantly less than at the rectum. There were no significant differences between the sites during the rapid rewarming in the 40°C water.

The duration of the afterdrop is shown in Figure 2. During the spontaneous rewarming, there were no differences between the temperature sites. However, during inhalation rewarming, the duration of the afterdrop at the esophageal site was significantly shorter than measured at the rectal or auditory canal and was also significantly shorter than rectal during the 40°C water immersion.

The rewarming rates calculated for each site are shown in Figure 3. There were no significant differences among the sites during the spontaneous and inhalation rewarming but during the rewarming in the 40°C water, both auditory canal and esophageal temperature sites increased in temperature significantly quicker than the rectal.

DISCUSSION

It is clearly evident from the results of this study that the esophageal site is the most sensitive to change in deep body temperature. It also follows therefore, that if esophageal temperature most accurately reflects aortic blood or cardiac temperature, the severity of the afterdrop or rate of rewarming on cardiac tissue would be overestimated when the other core temperature sites are used, especially when rectal temperature is monitored. This sensitivity to temperature change at the esophageal site may also influence the observations during inhalation rewarming and overpredict the efficacy of the technique in rewarming a subject. This may account for the high rate of rewarming using the inhalation technique suggested by Hayward and Steinman (10). Despite the accuracy and speed of response of the esophageal site, it is difficult to fit subjects with the probe and would be even more so in a field situation with a hypothermic victim.

The auditory canal temperature is often substituted fortympanic because of the discomfort associated with placing an object in contact with the tympanic membrane. Benzinger, Kitzinger, and Pratt (17) have

suggested that tympanic temperature may be a good indication of central brain temperature, especially of the thermoregulatory centre, the hypothalamus. Numerous studies have shown that tympanic or auditory canal temperature are both a reasonable measure of deep body temperature but would appear to be affected by external local cooling of the skin (18,19,20).

Our results would support such a view. Since the head remained exposed to the room air during the cooling, the conductive heat loss from about the head would be less than about the torso which was immersed in the water. The rate of cooling measured in the auditory canal was, as expected, somewhat slower than for either theesophageal or rectal temperature sites. Similarly, during the rewarming, the auditory canal temperatureтended to warm slower,although not significantly during the spontaneous and inhalation rewarming. The exception was during the rapid rewarming in the 40°C water when the skin temperature was significantly raised because of the hot water and auditory canal temperature rose at the same rate as esophageal. The auditory temperature site appears from our study to provide a good compromise solution to monitoring core temperature. It responds quicker than the rectal temperature site, which is known to be slow and is easier to fit on a subject than esophageal.

It is important to note that regardless of which temperaturesite was monitored, the conclusions regarding the efficacy of the various rewarming techniques are not altered (14). Also, during passively techniques, which provided small amounts of heat either spontaneously by shivering or by inhalation, there were no differences in the rate of rewarming among the different temperature sites.

The large differences in rewarming rates observed between rectal temperature and the other two sites during rewarming in 40°C water reflected the difficulties that can occur in determining when rewarming is complete. Relying only on rectal temperature could lead to erroneous conclusions. Recently, Popplow and Kuehn (21) stated rapid rewarming should be carried out in water not exceeding 38°C. They based their conclusions on subjects who felt overheated and faint after 20 minutes in 40°C water but had shown little rise in rectal temperature. By using the rate of rewarming to calculate the time to return the core temperature site back to pre-immersion values from the minimum valvue after the afterdrop, these subjects would have needed 43.5 minutes to have rectal temperature to return, while only 21 minutes for either esophageal or auditory canal. It is not surprising therefore, that Popplow and Kuehn (21) found their subjects feeling overheated when rectal temperature was the only measurement available. Webb (22) has pointed out that no core temperature gives areliable indication when all the heat lost has been restored. However, the sensitivity to change and the accuracy of esophageal temperature in representing cardiac tissue or aortic blood temperaturewould lead to suggest that it is the singlebest indicator of rewarming being complete.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions describing the efficacy of various techniques in rewarming mildly hypothermic subjects are not altered by which deep body temperature site is being monitored.

Esophageal temperature which has been shown previously to accurately epresent aortic blood or cardiac tissue temperature is the most sensitive to change during rewarming.

During rewarming with techniques which provide a slow rate of rise in core temperature, all three deep body temperature sites, rectal, auditory canal, and esophageal accurately reflect the change in temperature.

ACKNOWLEDGEMENTS

I would like to thank Mr. Robert Hoskin for his technical assistance during his participation and thank all the subjects who volunteered for the study.

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TABLE 1

Physical Characteristics of the Subjects (N=8)

	Height (cm)	Weight (kg)	Body Fat (%)
Mean±SD	179.9±7.5	76.8±5.5	13.8±6.4
Range	(167-190)	(68.5-85.0)	(5.0-21.5)

TABLE 2

Cooling Rates (°C/hr) Measured at Each Temperature Site During the Final 30 Minutes of Immersion Prior to Each Rewarming Technique

	Rectal	Esophageal	Auditory Canal
SR	0.86±0.57	0.88±0.53	0.69±0.26
IR	0.77±0.60	0.71±0.55	0.60±0.30
40 °C H_2O	0.89±0.62	1.08±0.71	0.68±0.27

SR - Spontaneous Rewarming; IR45 - Inhalation Rewarming with 45 °C; 40 °C H_2O - Rapid Rewarming in 40 °C Water

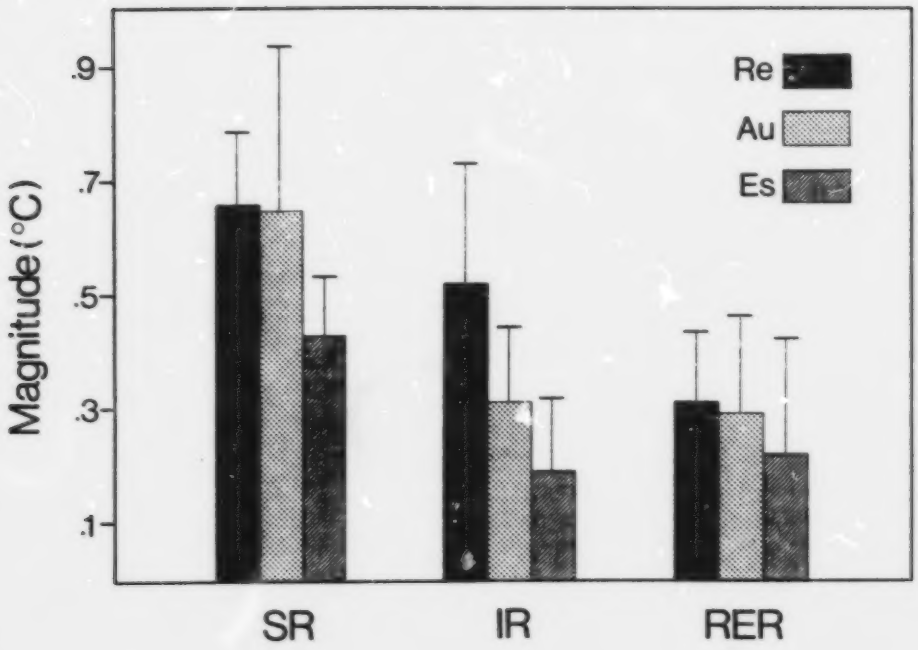

FIGURE 1

A comparison of the magnitude of afterdrop at each core temperature measurement site during each rewarming procedure.

Re - Rectal
Au - Auditory Canal
Es - Esophageal

SR - Spontaneous Rewarming
IR - Inhalation Rewarming with 45°C air.
RER - Rapid External Rewarming in 40°C water.

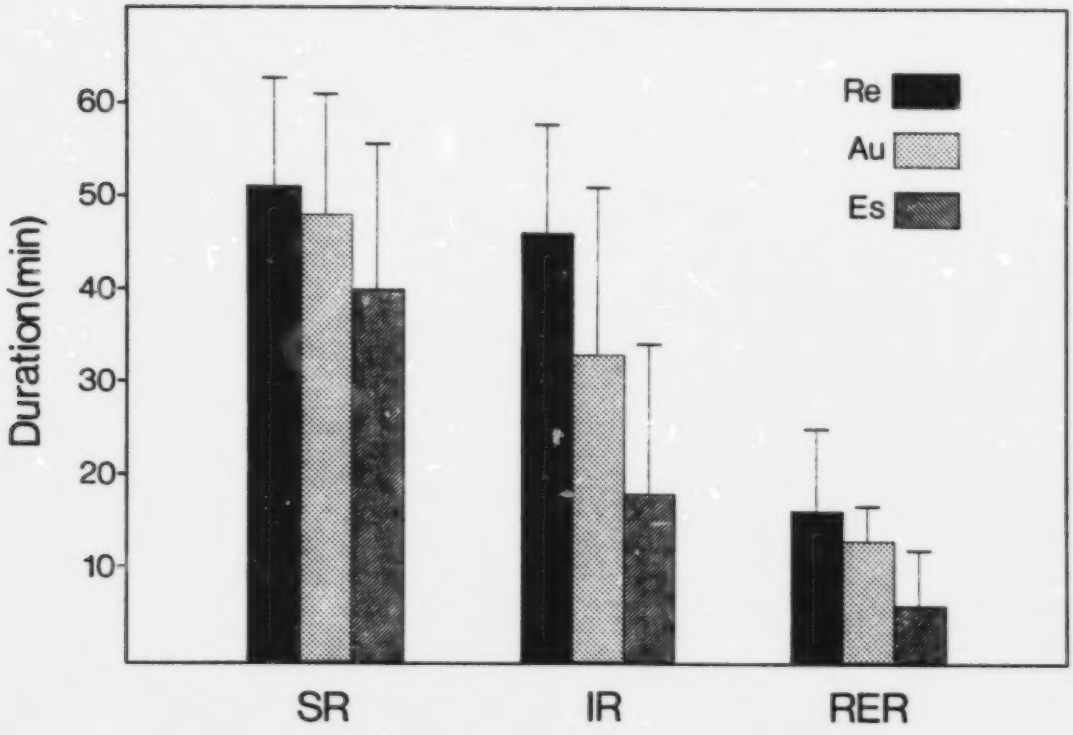

FIGURE 2

A comparison of the duration of the afterdrop of each core temperature measurement site during each rewarming procedure. (See Figure 1 for explanation of legend).

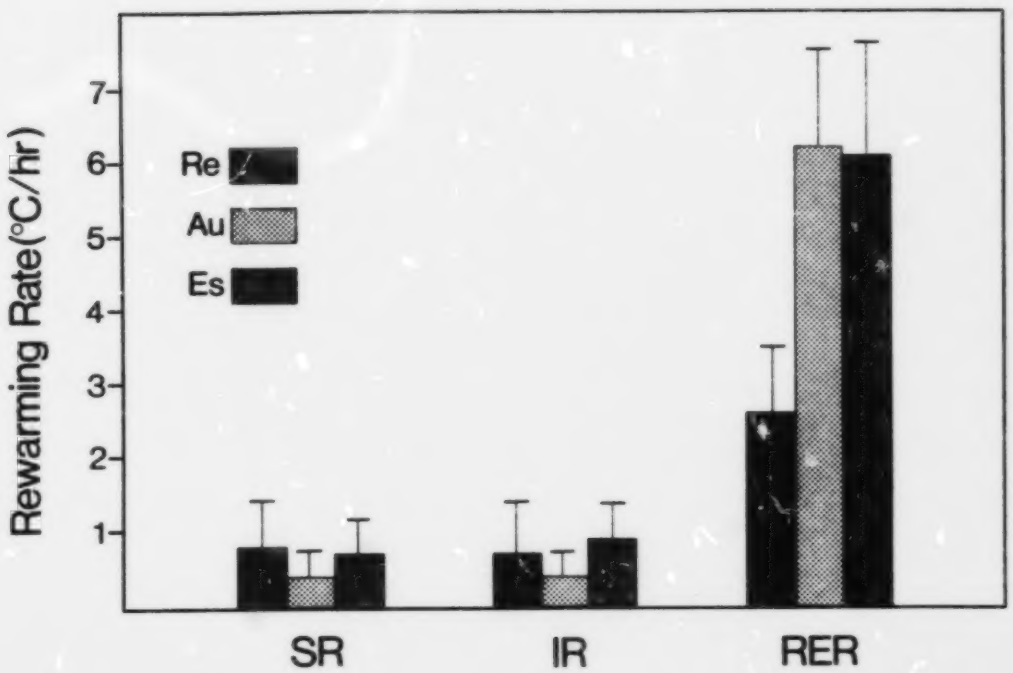

FIGURE 3

A comparison of rewarming rates calculated for each core temperature measurement site during each rewarming procedure. (See Figure 1 for explanation of legend).